UNITED STATES MARINE CORPS
MARINE CORPS SYSTEMS COMMAND
2200 LESTER ST
QUANTICO, VIRGINIA 22134-6050

IN REPLY REFER TO:

1000
PGD 15
24 Sep 04

FIRST ENDORSEMENT on HMMWV MTAP/RCM II Analysis Report of 13 Sep 04

From: Product Group Director, PGD15, Ground Transportation and Engineering Systems
To: Realignment of Maintenance Steering Team (ROMST)
Via: Acquisition Product Group MARCORSYSCOM

Subj: HMMWV MTAP/RCM II ANALYSIS REPORT

1. Forwarded for appropriate action

L. V. BRADLEY
By direction

UNITED STATES MARINE CORPS
MARINE CORPS SYSTEMS COMMAND
2200 LESTER ST
QUANTICO, VIRGINIA 22134-6050

IN REPLY REFER TO
11240
PM MT/KPD
13 Sept 04

From: Team Leader, High Mobility Multi-Purpose Vehicle (HMMWV), Maintenance Task Alignment Panel (MTAP)

To: Realignment of Maintenance Steering Team (ROMST)

Via: (1) Program Manager (PM), Motor Transport
(2) Product Group Director (PGD), Ground Transportation and Engineering Systems, (GTES), PG-15

Subj: (HMMWV) MTAP PHASE II REPORT

Ref: (a) CMC R 151833Z DEC 03, MARADMIN 581/03
(b) CMC R 311808Z DEC 03, Pilot Task to TAMCN (T2T) Individual Training Standards (ITS) Analysis
(c) CMC R 242125Z NOV 03 Results of Realignment of Maintenance (ROM) Working Integrated Process Team (WIPT)

Encl: (1) Concept of Employment (COE) for Light Tactical Vehicle Replacement (LTVR)
(2) Mission Needs Statement (MNS) for LTVR
(3) Operational Requirements Document (ORD) for LTVR
(4) Position Paper on HMMWV Task to TAMCN (T2T) using Reliability Centered Maintenance (RCM) II methodology
(5) The RCM II Audit
(6) The Realignment of Maintenance (ROM) Team Membership
(7) HMMWV Annual Condition Inspection (ACI) Checks
(8) HMMWV Phase II, Part I Report
(9) HMMWV Master Detail Document, Part I
(10) HMMWV Master Detail Document, Part II
(11) HMMWV Supplement Document
(12) Suspension and Winches Technical Information

2. **Executive Summary**: Message CMC R 311808Z DEC 03 (PILOT TASK TO TAMCN (T2T) INDIVIDUAL TRAINING STANDARD (ITS) ANALYSIS LOI) directed that a pilot Task to TAMCN (T2T) analysis be conducted on the HMMWV A2 using the Reliability Centered Maintenance II (RCM II) process currently being applied to the Expeditionary Fighting Vehicle (EFV). The overarching goal of this pilot is to provide a means to assess which structure, methodology and

processes will best support the Marine Corp's need for collecting baseline data with which to assess the impact of the realignment of maintenance (ROM) effort.

The results of the HMMWV study as contained in this report (subject to management audit of the decision and information worksheets as described in section 12) should be evaluated and compared with the results of the more traditional Course Content Review Board (CCRB) efforts that are also currently underway.

A team of eight Marines and one civilian was assembled to conduct an RCM II analysis of the M1123 HMMWV A2. After receiving a 3-day RCM class, the team assembled and began to analyze the various HMMWV subsystems. During the period 19 January - 4 February (weather caused some delay and resulted in a 3 day extension of the analysis), the team examined five HMMWV subsystems and developed comprehensive decision and information worksheets for each analysis.

The information and decision worksheets are included in this report and their data was used to develop the Task to TAM (T2T), design, training and PMCS recommendations that are also included herein.

For each of the more than 400 failure modes identified during this analysis, the group determined who should diagnose the problem and who should repair it. This forms the basis for the T2T recommendations. The missing elements from the T2T piece, which this group had neither the time nor the right representation to determine: the rank at which the Marine should be expected to do the task without supervision; the MOS; where the task should be taught; and how often it should be repeated to retain proficiency.

The RCM II process is not intended as a tool to simply reduce the PMCS burden by eliminating tasks or lengthening intervals. Instead, it is a methodical process used to determine (and thoroughly document) the effects of failure so that an evaluation of the consequences can be done. After the consequence evaluation, an intelligent decision (based on a clear set of scientific guidelines) concerning what to do about each failure can be made.

This report does not contain a statistical comparison of the "before" and "after" with respect to PMCS tasks on the HMMWV.

Subj: (HMMWV) MTAP Phase II Report

It does contain a more defensible list of recommended tasks (which can be accomplished in a far shorter amount of time) than either the current technical manuals or the emerging annual condition inspection for this vehicle. Statistical comparisons do nothing by way of determining whether a task is the right one and whether the prescribed interval is correct and are therefore, not included here.

If more specific information about the RCM II process as it relates to the contents of this report is desired, CWO-5 Jim Gehris can be contacted at gehrisj@aaav.usmc.mil.

3. **Team Membership**: Corps participants are highlighted in RED, while others provided top-level rudder. Not contained on the below roster is Mr. Dave Lick from HQMC, I & L who joined in on many of the sessions, provided tremendous insight on the new 3 levels of maintenance as well as sharing his experiences.

BILLET	RANK	L NAME	FIRST	UNIT	PHONE NUMBER
I & L	Lt Col	Lasure	Ken	CMC LPV-4	703-695-5939 (DSN 225)
LOGCOM	CIV	Swin	Warren	MCLB	229-639-6976 (DSN 567)
TECOM	Capt	Parker	K	FLW	573-596-0131 x68634
T2T COORD	CW05	Deluca	Kevin	GTES-PM-MT	703-432-3645 (DSN 378)
T2T ASST	MGySgt	Favor	Henry	GTES-PM-MT	703-432-3660 (DSN 378)
MTM SUPERV	CW02	Fuller	Andrew	II MEF 2 FSSG	703-451-6004 (DSN 751)
MTM SUPERV ASST	GYSGT	Brown	Jim	II MEF 2 FSSG	910-451-1322 (DSN 751)
MT MECH	CPL	Barrington	N	II MEF 2 FSSG	
MT OPERATOR	SSgt	Celmer	T	II MEF 2 FSSG	
GTES PG REP	MS	Boddy	Natalie	SBT LOG	703-432-3711 (DSN 378)
GTES PG ENGR	Ms	Redfern	Julie	SBT ENGR	703-432-3709 (DSN 378)
MCSC PG REP	Mr	Chappell	Rob	ACPROG	703-432-3825 (DSN 378)
HMMWV OEM					
MT SCHOOL REP	GySgt	Booker	James	MCCSSS	910-450-0835 (DSN 835)
RCM II FACILATOR	CW05	Gehris	James	EFV WB Va	703-490-7505
RCM II DOCUMENTER	CIV	Muncy	Lyle	EFV WB Va	703-490-7263
EFV	Civ	Walker	Montgomery	EFV WB Va	
ACPROG	Civ	Romero	Yvonne	AC PROG	703-432-3789 (DSN 378)
ACPROG	Civ	Decarlo	Armondo	SBT ENGR	703-432-3669 (DSN 378)
GTES PM-MT	Civ	Baines	Annete	HMMWV LOG	703-432-3599
GTES PM-MT	Civ	Mimms	Mike	LOG MNG SPEC	703-432-3627
GTES PM-MT	Capt	Rodgers	Andy	HMMWV PO	703-432-5482

4. **Facilities & Environment**: The Transportation Demonstration Support Area (TDSA) was the facility utilized for the month long HMMWVA2 analysis. Master Sergeant Jack Heric hosted the team, made the HMMWVA2 available and provided a superb climate to work through the RCM II process. I believe getting away from the usual work environment and into an area that is well suited for this type of activity played a very useful role in that all members did not feel any stress or friction to agree with local command policies. We dressed in civilian attire and did not refer to our military rank while working through the process. Initially a little difficult to get used to, it ended up being the correct method to work the process effectively. RCM did not prosper in it's first iteration however, the time and the environment of today's very high and demanding operational tempo makes this process much more realistic and well worth pursuing.

5. **The Analysis**: This analysis was led by CWO-5 Jim Gehris and Mr. Lyle Muncy; both of whom are licensed RCM II practitioners assigned to the EFV program office. The group members identified to participate in the analysis are depicted in section 4 and were required to attend a 3-Day RCM Overview Course prior to starting the analysis. The course was conducted 13-15 January 2004 and is designed to introduce a group to the RCM II concept and to provide each with a thorough understanding of the process used to conduct the analysis.

The time allotted for this analysis permitted examination of only one HMWWV A2 variant, the M1123. The group considered the M1123 as the baseline variant for all HMWWV A2 models and thus selected it. Similarly, time only allowed for examination of one operating context (environment) - the temperate environment similar to that found at Camp Lejeune, North Carolina was selected. The group quickly recognized that there are a multitude of operating contexts, which should be considered when establishing maintenance policy. This HMMWV analysis should be examined at some future date with respect to other operating contexts - i.e. jungle, desert, arctic and MPS in which it is likely to operate. Additionally, using this operating context as a start, it is recommended that the other HMMWV variants be examined at some future point with this baseline analysis serving as the template.

Given the wide latitude afforded Marine Commanders to modify HMMWVs in support of specific missions, the group decided that

this baseline analysis could only sensibly be conducted on a vehicle configured as per published technical manuals. Therefore, the requirements for and configuration of the M1123 analyzed is as represented in the following documents:

- Operational Requirements Document (ORD) for the Light Tactical Vehicle Replacement (LTVR) dated 6 August 1998
- ULSS 001378-15 Dated 3 March 2003
- TM 2320-10/6B Dated January 1996
- TM 2320 -20/7B (Volumes 1,2 and 3) Dated January 1996
- TM 2320-24P/8B Dated March 2001
- TM 2320-34/9B Dated January 1996

The initial plan for the M1123 overall analysis consisted of 7 individual RCM II "sub-system" analyses. Because of time constraints the first 5 were completed in February and the last 2 in July 2004.

1. Body
2. Brake System (Service and emergency)
3. Electrical
3. Power Train - includes:
   - Engine
   - Fuel System
   - Cooling system
   - Air intake and exhaust
   - Transmission
   - Transfer case
   - Differentials
   - Drivelines
5. Steering system
6. Suspension - includes chassis, frame, cross-members, tires and rims (time did not permit)
7. Auxiliary systems (such as the winch)

The overall analysis took slightly longer than projected because the composition of the group did not include a HMMWV operator (MOS 3531) or "experts" on the HMWWV transmission or electrical system; as a result, the suspension and auxiliary systems were not examined. The group felt they were mature and therefore not a source of maintenance problems. Although the group finally arrived at failure modes and effects for the transmission and electrical system, the time to research available technical publications was time consuming. The research included calling

subject matter experts when questions the group could not answer arose.

Note: This reinforces the RCM II position that having the "right people" - those who know the equipment best - in an analysis increases the speed with which the analysis can be completed. It should be noted that even without "experts" on individual systems, there is little impact to the accuracy and thoroughness of an analysis given an experienced facilitator. The impact is generally limited to the increased time it takes to complete an analysis. In spite of the absence of "experts", the HMMWV review group averaged more than 7 failure modes an hour over the course of the analysis. This rate is comparable with much more experienced review groups and is much better than the industry standard.

Analysis Hours - about 80
Analysis conducted - 7
Statistical details:

Analysis	Total failure modes	Hidden	Safety	Environmental
Body	82	2	27	0
Brakes	47	8	9	0
Electrical	87	16	4	0
Powertrain	178	3	5	36
Steering	45	0	2	15
Suspension /Aux Systems	90	25	20	0
TOTAL	529	54 (6%)	67 (10.7%)	41 (9.3%)

Note: The relatively few failure modes with hidden, safety or environmental consequences reflect the maturity of the automotive design process in general and specifically, the HMMWV.

Analysis outputs

Each analysis is fully documented by way of an information worksheet and a decision worksheet. These can be found in sections 13, 14, 15, 16 and 17. When combined, these documents

provide a powerful diagnostic tool. They also provide a comprehensive and fully auditable trail where each decision and recommendation can be traced back to a requirement (function). Moreover, the effects (and consequences) of each failure mode for which a recommendation is made are fully explained. The information in these documents was developed using the RCM II process, which consists of a trained facilitator asking the review group the following 7 questions, in the listed order, for each system under review:

1. What is the function?
2. At what point is it failed?
3. What causes the failure?
4. What happens when it fails?
5. Does it matter?
6. Can we do anything to predict or prevent the failure?
7. What if we can't predict or prevent the failure?

Question 1 establishes why the system exists. Questions 2, 3 and 4 establish failed states and identify failure modes and effects. Questions 5 determines the consequences of each failure mode and question 6 provides recommendations for predictive and preventive tasks (PMCS tasks) based on RCM II logic. These tasks are detailed in section 11 and are separated between I-Level maintainers and operators. A more thorough discussion of these tasks follows in a later section entitled predictive and preventive tasks (PMCS).

If a predictive or preventive task in response to question 6 cannot be determined, the RCM II process provides for defaults to avoid the consequences of failures that matter. When no predictive or preventive task can be found, question 7 (What if we can't predict or prevent the failure) provides for several sensible alternatives.

- In the case of failure modes with safety or environmental consequences, redesign is compulsory. The redesign may be in the form of a one-time change to actual vehicle hardware or design. It can also be a change to a technical manual, operating procedure or an increased emphasis in training. In RCM II terms, "redesign" is a global term that suggests changing "something" to avoid the consequences of failure.

- In the case of hidden functions, a failure finding task with an appropriate interval may be recommended. The formula for determining the interval for most failure finding tasks is described in section 7. It should be noted that hidden functions always apply to protective devices and that failure-finding tasks are designed to ensure that the protective device is not in a failed state. Hidden functions are generally poorly understood and, as a result, are frequently overlooked in failure management policies. As an example, in the current HMMWV technical manuals, there are no provisions for proactively checking the brake warning system to ensure it is fully functional. Similarly, even though there is a check of the neutral safety switch, the prescribed method, in contrast to the RCM II concept, does not check the system as a whole.

- In the case of failure modes without safety or environmental consequences, "No scheduled maintenance" may be selected as the default action when specific established criteria are met. Although counter-intuitive to many with extensive maintenance backgrounds, "no scheduled maintenance", or "run to failure" is a perfectly logical failure management policy if the consequences of the failure don't matter.

- In any case, where the consequences are not environmental or safety related, redesign might be a desirable alternative.

Although scheduled preventive, predictive or failure finding tasks constitute the bulk of the recommendations contained in section 11 of this report, 28 specific recommendations for redesign are contained in section 9, and 94 specific training related recommendations are contained in section 10.

Task to TAMCN

For each failure mode described in this analysis, two questions are answered. "Who should diagnose it and how long does it take' and "Who should repair it and how long does it take?" In each decision worksheet, at the end of the description for each failure effect, the terms "TTD" (Time To Diagnose" and "TTR" (Time To Repair) are used to indicate answers to these questions. The results of this effort are detailed in section 8 as "T2T recommendations". Although the review group indicated the level that each task should be performed (O, I or D), time did not permit a more comprehensive analysis. Moreover,

although there were representatives from the maintenance and operator schools, they did not have copies of their respective POIs or applicable ITS.

For PMCS tasks, the examination of "who should do the task" cannot sensibly be conducted until an analysis such as this is completed because without this type of analysis, those tasks cannot be properly defined.

Identifying "who" (Operator or I-Level) is only the first part of a true T2T analysis. As shown in section 8, once the task and the "who should perform it" are identified, additional steps must be taken to define:

- The MOS of the person doing the task
- The rank at which they should be able to do the task without supervision
- Where the task should be learned (ie. Formal school, OJT, distance learning, mobile training team, etc.)
- The frequency with which the task should be performed to retain proficiency (ie. Once a year, once every 6 months, etc.)

These steps in the process can be accomplished quickly, assuming the right people are making the decisions. As stated above, however, these steps cannot logically be undertaken (except for purely corrective maintenance and operating tasks) until an analysis determines exactly what "the right job" is.

As a note, this analysis does not consider logistics delay time because of its variance and variables; it assumes that parts and tools are on-hand for each task when it defines "TTD and TTR."

As an additional note, the group expressed concern repeatedly during the analysis that tasks identified at the "O" level, particularly when accomplished by an incidental operator, must be properly supervised and inspected by qualified personnel at completion to ensure that they are done properly. "Training" (or a real or perceived lack thereof) was a recurring recommendation.

Predictive and preventive tasks (PMCS)

An annual condition inspection (ACI) checklist for the HMMWV was provided to the analysis team for use in this effort. Although

we examined the more comprehensive PMCS schedules contained in the vehicle technical manuals, the ACI checklist is the baseline for this report.

The ACI checklist is apparently the result of relatively recent analysis performed by the Reliability Analysis Center (RAC) and a working group comprised of Marines from the motor transport maintenance, operator and logistics community. Some of this review group's members knew about the checklist but not all are using it. This ACI checklist is, in part, the result of a larger DoD/USMC effort to reduce the PMCS burden throughout the services.

In most Marine Corps units (indeed, in the services in general), the focus is in training the Marine to do the job properly ("doing the job right") and in making sure that all hands know what those jobs are. The RCM II process suggests that the first step in PMCS reduction is to ensure that the Marine is "doing the right job". Currently, as measured by the ACI checklist provided this review group, the HMMWV maintenance policy is not geared toward doing "the right job".

An annotated copy of the HMMWV ACI checklist is included in section 18. Of the 78 tasks on the checklist that apply to the A2 variant, (a few of the tasks, such as the air system dump valve, don't apply to the A2 but are not marked as such), the following is noted:

- Only 6 (10%) are supported by this RCM II analysis as valid;
- 65 (83%) are not supported by this analysis;
- 5 of the tasks were not subject to analysis as they belong to the suspension group.

In one case, this analysis suggests that a currently scheduled annual task be done twice a year (inspecting brake lines and fittings for corrosion); in another, a biennial interval is recommended. (Check CV boots for deterioration).

As mentioned earlier, section 11 contains specific tasks for the I Level and operator with suggested intervals for those tasks. The recommended tasks represent a significant reduction (requiring substantially less time) when compared to the tasks listed in equipment TMs and the ACI and more importantly, can be justified from a science-based logic perspective.

The I Level tasks suggested by this analysis fall into several general areas. There are two failure-finding tasks (neutral start switch and brake warning system) and several tasks to determine whether rubber hoses and lines are failing due to deterioration. There are also several tasks to determine whether specific seals and gaskets are failing due to deterioration and 3 tasks examine the condition of lubricating oil.

Similarly, operator tasks fall into several general areas. Almost half involve failure-finding tasks as determined by the failure finding calculation (discussed in section 17). About a third are done on a scheduled basis (ie: quarterly, annually) as determined by either failure finding or the P-F interval of the component. The P-F interval is explained later in this section. Conducting a statistical comparison of the "before and after" as it related to PMCS tasks for the HMMWV is beyond the scope of this analysis. As noted earlier, the primary function of RCM II is not to "reduce" PMCS - it's to ensure that the right jobs are being scheduled.

With respect to the intervals at which the tasks should be performed, Marine Corps usage of the HMMWV presents a unique challenge as described below.

HMMWV operational usage

Operations of the HMMWV vary widely from unit to unit. Recent studies of a small sample size (22 vehicles), for example, showed that the highest annual total was 7,705 miles for one vehicle while the lowest was 9 miles. Similarly, the highest monthly total for a single vehicle was 397 miles while the lowest was 0 miles.

Given this, it's extremely unwise to develop a PMCS program based on miles alone. At the same time, most of the components examined do not have a calendar based "life". In fact, fewer than 20% of all components in physical assets have a "life" - or an age at which there is a rapid increase in the conditional probability of failure. Therefore, it does not make sense to develop a PMCS program strictly based on calendar time either. Furthermore, the HMMWV (the exception is the communications variant) does not have an hour meter installed so it is presently impossible to establish a PMCS program based on hours

of engine or master switch operation. For components that do not have a "life", one can consider the "P-F" interval, if one exists, as part of a maintenance management policy. Unfortunately, the P-F interval is poorly understood.

The "P-F interval" is the time from when a warning that something is failing can be detected until the time that the item has failed. This interval is used to establish an on-condition task. This is commonly referred to as "condition based maintenance", or CBM. When something is subjected to an on-condition task, it's left in service on the condition that its performance is still satisfactory. (Or, in other words, that the warning has not been observed). CBM is an emerging field and is the subject of much attention at the DoD level. However, fewer than 25% of components exhibit characteristics that make them sensible candidates, base on their P-F interval, for a CBM program.

In section 11 (PMCS tasks), those tasks that were established based on the P-F interval as determined by the review group contain the interval. In several instances in this section, the unit of measurement is either miles or age, whichever comes first.

As an aside, measures should be taken to ensure that the emerging GCSS-MC system supports this multi-dependant form (miles versus time) of efficient PMCS scheduling. Moreover, consideration should also be given to equipping each HMMWV with an hour meter to measure engine running time as a basis for scheduled maintenance since a number of items exist which have that can be linked to hours of operation. .

If the tasks recommended in this analysis are adopted, they should be monitored on a fleet-wide basis over time, and if required, the interval should be adjusted based on findings.

Technical Manuals

As mentioned earlier, this group lacked "experts" on the transmission and electrical systems. Because of this, they were also hampered by the lack of theoretical detail contained in the Army technical manuals. None of the published manuals contained satisfactory explanations of system operation and system interdependencies. If not for the availability of one group member's training manuals published by the AM General

Corporation, operational details for some systems could not have been determined. In addition to the general lack of theoretical information, technical problems were noted with the publications. For example, vehicle voltage specifications varied among (and within) volumes:

TM 2320-34/9B - chap 6-5.1 page 6-44.4: 26-30 volts given as spec for alternator output.
TM 2320-20/7B volume 1 w/ch1 page 2-224.7: 26-30.5 volts given as spec for alternator output.
TM 2320-20/7B volume 1 w/ch1 page 2-198: 27-29 volts given as spec for alternator output.
The AM General publication: 26-30.5 volts given as spec for alternator output.

In another instance, TM 2320-10/6B, page 3-6 item 17 said "Step 2. Check for low brake fluid level (TM 9-2320-280-20). Add brake fluid (Appendix G)." however, appendix G does not address brake fluid.

Representatives from the PM Motor Transport office indicated that they would take appropriate action regarding technical manual shortfalls.

Administrative notes pertaining to the decision and information worksheets

Keywords:

In these analyses, keywords are used for brevity. See failure mode 1A1 in each separate analysis for a listing of keywords used in that analysis. With respect to failure modes and any effects related to safety, the probability of occurrence and severity, based on the best estimate of the group, was assigned based on the Hazard Severity Categories and Probability established by MIL-STD-882C and detailed in section 6 of this report.

Manufacturing:

The group realized that improper manufacturing can lead to failure. In the context of the HMMWV, however, they believe that sufficient safeguards (and the maturity of the design) are in place to mitigate this as a failure mode. Accordingly, no failure modes related to improper manufacturing were addressed in this analysis.

Cable failure mode conventions:

The group realized that cables can fail for various reasons. Among the failure modes: pre-bending stress (caused by poor routing schemes); improper installation (caused by inadequate technical manuals/training); chaffing (cause by poor routing design that results in the cable abrading against another object), corrosion (caused by inadequate connectors and/or backshells); and hit by foreign object (HBFO) (caused by the cable being positioned in such a manner as to make it vulnerable to damage). In this analysis, only one generic failure mode ("fails") will be examined for cable problems unless the review team has experienced specific failure modes on specific cables. In those instances, more detailed failure modes will be described.

Summary:

This RCM II pilot project has provided a wealth of information regarding the HMMWV A2. Every group member benefited from the synergy typical of an RCM analysis and the recommendations contained in this report will withstand the closest scrutiny.

In order to achieve the Marine Corp's vision with respect to modernizing the logistics enterprise, a generational shift in thinking must occur and many long-standing cultures must be changed. RCM II provides the framework for doing this efficiently and with maximum results. This process, as proven through use in the EFV program, can be used to analyze nearly every form of human endeavor with stunning speed and success. It is the ideal process to form the cornerstone for the transformation the Marine Corps has in mind.

6. Transition to Phase III: We feel we have given a very good look at the HMMWVA2 and have 2 documents (10 Feb & 28 July 2004) that provide a road ahead on moving from 5 to 3 levels of maintenance with minimal impact on the length of training in MOS producing schools. During phase 3 we will focus on cost, tools, facility challenges, supply support change initiatives, formal school additional requirements and other subjects as may be appropriate. With the pace of current activity our Phase III data will be 2-3 months in the gathering, studying, and analyzing for formal packaging and forwarding via the Chain of Command to HQMC, I & L.

Subj: (HMMWV) MTAP Phase II Report

KEVIN P DELUCA
CWO-5 USMC